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ORIGINAL RESEARCH ARTICLE

Preliminary investigation on nutritive potential of four selected browse fodders in southern Guinea savannah, Nigeria

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ABSTRACT
Scarcity of forages for grazing stock during the dry season necessitates continuous screening and re-screening of novel or underutilized browse species with the aim of discovering those with potential nutritive value that can be exploited for feeding animals in the developing countries of the world. The objective of this study was to evaluate nutritive potential of four selected browse fodders (*Piliostigma thonningii*, *Detarium microcarpum*, *Stereospermum kunthianum* and *Isoberlinia doka*) by considering some of their nutritional and anti-nutritional properties. Dry matter and organic matter contents were not different (P>0.05) among the browses. *D. microcarpum* had the highest (P<0.05) levels of crude protein and ether extract contents, whereas ash and oxalate contents were lowest (P<0.05) in *S. kunthianum*. Crude fibre was greater (P<0.05) in *P. thonningii* and *I. doka* than in *D. microcarpum* and *S. kunthianum*. Calcium level was higher (P<0.05) in *S. kunthianum* and *I. doka* compared to *P. thonningii* and *D. microcarpum*, which had similar contents. Phosphorus and potassium contents were greatest (P<0.05) in *S. kunthianum*. Magnesium concentration was greatest in *D. microcarpum* and *S. kunthianum* and lowest in *P. thonningii* (P<0.05). Concentrations of condensed tannins, saponins, phytate and oxalates were higher (P<0.05) in *I. doka* than in other browse fodders. The concentrations of all the phytochemicals were below the threshold levels at which they induce toxicity in ruminants. The results indicate that the studied browse species are promising fodders that can either be fed solely or used as supplements to the inherently low nutritive tropical forages or roughages predominantly used for ruminant feeding in smallholder ruminant production systems.

Keywords: browse fodder, fibre fraction, phytochemical component, mineral composition, nutritive potential

INTRODUCTION

Browse species are widely distributed throughout the savannah zone of Nigeria and represent a significant resource for the large population of ruminants, which are predominantly grazed on the rangeland, in this area. Foliage from these species may represent a high proportion of the feed ingested by sheep, cattle and goats (Van Soest, 1994). In Nigeria, rangelands are the major sources of fodder for the traditionally-managed ruminant stock (Olafadehan and Adewumi, 2009). Promotion of suitable and nutritionally better browse or fodder species could be a practical approach to reduce fodder scarcity during long periods of drought and to meet nutritional requirements of many categories of animals. The ability of the browse foliage to remain green and maintain their CP content makes them potential sources of protein and energy for sustainable ruminant production (Olafadehan, 2013). However, some of these plants contain phytochemicals, especially tannins, which can either be detrimental or beneficial to animals depending on their concentration or type (Olafadehan, 2011; Patra and Saxena, 2011). Up to date, *Leucaena leucocephala* and *Gliricidia sepium* have been the most widely studied and utilized conventional trees in livestock nutrition in Nigeria. However, despite their evergreen foliage throughout the year and nutritive value, many browse species have been generally undervalued mainly because of paucity of knowledge about their potential feeding value. Chemical analysis can help in the preliminary evaluation of the potential nutritive value of tree species, which were not investigated previously. Thus, detailed investigation on browse species is very important in order to identify the better ones in terms of nutrient content and anti-nutritional components. The objective of this study was to assess the potential nutritive value of some four selected novel browse species based on their chemical composition and anti-nutritional content. This rapid method has been used to screen feed resources before making them available to livestock.

MATERIALS AND METHODS

Collection and processing of browse leaves

Fresh leaves of *P. thonningii*, *D. microcarpum*, *I. doka and S. kunthianum* were harvested from several stands of the trees in Federal College of Wildlife Management, New Bussa, Niger State. Samples of the fresh leaves of the four browse fodders were oven-dried to constant weight at 60 °C for 72 h for dry matter determination. The dried leaf samples were then ground to pass through 1 mm sieve to produce leaf meals which were stored in individual labelled bottles pending analyses.

Chemical analysis

Dried representative samples of the leaf meals were analysed in triplicate for their crude protein (CP), crude fibre (CF), ether extract (EE) and ash according to AOAC (1995) procedures. The neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined by the methods of Van Soest et al. (1991). Cellulose and hemicellulose were calculated as the differences between ADF and ADL, and NDF and ADF respectively. Condensed tannins were determined by the methods of Makkar (2003) and saponins by the methods of Babayemi *et al*. (2004). The methods of Maga (1982) and AOAC (1995) were used for phytate and oxalate determinations. Minerals, Ca, Mg and P, concentrations were determined using the Pye-unicam atomic absorption spectrophotometer, and K and Na were analysed using flame photometer.

Data analysis

Data were subjected to one-way ANOVA using complete randomized design procedure of SPSS Base 15 (SPSS software products, USA), and treatment means were separated using Duncan's multiple range test of the same software.

RESULTS AND DISCUSSION

The similar (P>0.05) DM values of the browse species are within the range of 922.6 to 984.6 g/kg reported by Njidda *et al*. (2013a) for some semi-arid browses in Nigeria (Table 1). The CP contents, which are within the range of 134.5 - 181.8 g/kg DM reported by Njidda *et al.* (2013a), were highest in *D. microcarpum*, intermediate in *P. thonningii* and *I. doka* and lowest ($P<0.05$) in *S. kunthianum.* The CP values of the browse foliages are above the 8% minimum level required for optimal rumen microbial function (Norton, 2003), which indicates that the fodders could support maintenance requirements and some production levels in ruminants (Van Soest, 1994). The leaves of the browses are thus potential CP supplement for ruminants in the tropics and can also be incorporated into ruminant rations to substitute for the expensive conventional protein sources.

Table 1: Proximate constituents of the experimental fodders

	P. thonningii	*D. microcarpum*	*S. kunthianum*	*I. doka*	SEM
Dry matter	95.11	94.27	95.05	94.31	0.70
In % dry matter					
Crude protein	16.10^{b}	18.19^{a}	13.25^{c}	16.38^{b}	0.20
Organic matter	89.12	88.46	90.01	89.11	1.55
Crude fibre	31.75^{a}	25.19^{b}	27.92^{b}	33.17^{a}	1.89
Ether extract	4.02^{c}	5.54^{a}	4.88^{b}	3.99^{c}	0.14
Ash	10.88^{a}	11.54^{a}	9.99^{b}	10.89^{a}	0.45
Total carbohydrate	69.06^{a}	64.73^{b}	71.88^{a}	68.74^{a}	1.35
NSC	26.79^{b}	29.06^{a}	27.42^{ab}	13.53^{c}	0.69

^{abc}: Means in the same row with different superscripts are significantly different ($P<0.05$).
NSC: non-structural carbohydrate =100 - (NDF + CP + EE+ Ash) % DM.

Table 2: Fibre fractions (% DM) of the experimental browse fodders

	P. thonningii	*D. microcarpum*	*S. kunthianum*	*I. doka*	SEM
Neutral detergent fibre	42.21^{c}	35.66^{d}	44.40^{b}	55.21^{a}	0.88
Acid detergent fibre	31.07^{b}	24.30^{c}	30.49^{b}	36.35^{a}	0.66
Acid detergent lignin	10.87^{c}	12.54^{b}	7.52^{d}	15.04^{a}	2.63
Hemicellulose	11.14^{c}	11.37^{c}	13.91^{b}	18.86^{a}	0.53
Cellulose	20.20^{a}	11.76^{b}	22.97^{a}	21.31^{a}	0.85

^{abc}: Means in the same row with different superscripts are significantly different (P<0.05).

Organic matter (OM) contents of the browse sp. showed no (P>0.05) difference and are within the range of 836 - 910 g/kg reported for some browse species in Nigeria (Fadiyimu *et al*., 2011). The generally high OM content of the browse fodders indicates their potential as good sources of energy, because the OM of a feed reflects its potential energy value. The CF contents, which were higher (P<0.05) in *I. doka* and *P. thonningii* than in *D. microcarpum* and *S. kunthianum*, are higher than the range (14.0-17.2% DM) indicated by Fadiyimu *et al*. (2011). The EE contents are generally low and were highest in *D. microcarpum* and lowest in *P. thonningii* and *I. doka* (P<0.05). The generally low EE content of the browse fodders suggests that they would not pose problem such as rumen acidiosis and/or displaced abomasums which have been associated with high dietary EE. The ash levels are within the range of 70.6 - 180.6 g/kg DM obtained by Njidda *et al*. (2013a). The relatively high CP and low CF contents of the browse sp. suggest that they are good sources of nutrient supplements in ruminant nutrition. Both total carbohydrate and non-structural carbohydrate (NSC) contents are used to depict soluble or readily fermentable carbohydrates and are important in ruminant nutrition for checking acidosis and other metabolic related disorders. Total carbohydrate was lowest (P<0.05) for *D. microcarpum* compared to other browse sp. The values obtained compared favourably with that (64.55 – 75.93% DM) reported elsewhere (Okunade *et al*., 2014a). The NSC content differed among the browses and was marginal (P<0.05) for *I. doka* relative to other browse fodders, but was within the ranges previously reported (Okunade *et al*., 2014a, b). The quantity and rate of fermentability of NSC affect ruminal pH, volatile fatty acids production and incorporation of the ruminal NH_3–N into microbial protein (Olafadehan and Adebayo, 2016; Olafadehan *et al*., 2016). It appears that the NSC contents of the browse species are adequate to stimulate NH_3–N utilization in the rumen (Tylutki *et al*., 2008). Based on the available data (NRC, 1985), it appears logical to infer that the browse fodders would be able to meet nutrient requirements of ruminants at all physiological states.

The fibre fractions of the experimental browse fodders are shown in Table 2. The fibre contents (NDF, ADF, ADL, cellulose and hemicellulose) have implication on the intake and digestibility of plants. The NDF level was highest and lowest (P<0.05) in *I. doka* and *D. microcarpum* respectively. The NDF contents of the browse fodders are similar to range of 34.36 - 54.56 g/100g DM obtained by Okunade *et al*. (2014b) and below the 600 g NDF/kg DM threshold content beyond which feed intake and digestibility are adversely affected in ruminants (Meissner and Paulsmeier 1995). The ADF, ADL and hemicellulose contents were highest (P<0.05) for *I. doka* compared to the other browse sp. The obtained values are with ranges reported for browse fodders in the northern Guinea and Sahel savannahs of Nigeria (Njidda *et al*., 2013b; Okunade *et al*., 2014a, b). Cellulose was lower in *D. microcarpum* relative to other browse sp. The generally relatively high structural carbohydrates contents of *I. doka* may have some implication on its fodder value because fibre forms bulk and reduces the rate of passage of the digesta through gastrointestinal tract, resulting in reduced feed intake and digestibility (Olafadehan *et al*., 2014). The high CP and moderate fibre contents of the tree fodders would be beneficial to voluntary intake and digestibility of poor quality roughage (Okunade *et al*., 2014a).

Though Ca level (Table 3) was greater (P<0.05) in *S. kunthianum* and *I. doka* than in *P. thonningii* and *D. microcarpum*, all the browse fodders have sufficient Ca concentrations that meet the requirement (1.9 – 8.2 g/100g DM) of ruminants (McDowell, 1997). The Ca concentrations are similar to the previously reported levels in browse fodders of semi-arid region of northern Nigeria (Njidda and Nasiru, 2010; Njidda *et al*., 2013b). Phosphorus content was higher (P<0.05) in *S. kunthianum* than in other fodders. Njidda *et al*. (2013b) reported much higher values than the values obtained in the present study. However, the values obtained are within the established range (1.2 – 4.8 g/100 g) considered adequate for all classes of ruminants (McDowell, 1997) but are higher than the mean value of 2.7 g/kg DM reported for tropical pastures (Minson, 1990). Variation in results may be due to the available soil P and pH, browse growth stage, proportions of leaf and stem fractions used for analyses and sampling season. Potassium content varied (P<0.05) among the browse species; the rank order was: *S. kunthianum*>*P. thonningii*>*I. doka*>*D. microcarpum*. Based on the K requirement of 1.8 - 2.5 g/kg DM for goats (NRC, 1985), ruminants being browsed or zero grazed on these browse species would have adequate access to K. The K levels are higher than the concentrations reported by Okunade *et al*. (2014b), within the range reported by Njidda *et al*. (2013b) and lower than the values shown by Njidda and Nasiru (2010). Magnesium concentration was (P<0.05) highest in *S. kunthianum* and *D. microcarpum* and lowest in *P. thonningii*. Based on the recommended values of 0.08-0.25% (Kessler, 1991) and 2.0 g/kg DM (Minson, 1990), the Mg contents of the browse fodders would suffice for all classes of ruminants. According to Shamat *et al*. (2009), Mg is not a limiting mineral in tropical forages. Sodium content was similar (P>0.05) among the browse sp. and appears to be generally low in all the browse sp., except for *D. microcarpum* and *I. doka* which meet the minimum requirements for ruminant feeding (NRC, 1985). The sodium contents of all the browse fodders are lower than 0.7 g/kg required in the diet of goats (Kessler, 1991). Tropical pastures have been reported to be deficient in Na (Aregheore, 2002). Based on the major mineral profile of the browse fodders, it appears plausible to say that the foliage of the four browse species can be used as sources of mineral supplement for ruminant stock in Nigeria. However, there may be the need for Na supplementation.

Table 3: Mineral composition (% DM) of the experimental fodders

	P. thonningii	*D. microcarpum*	*S. kunthianum*	*I. doka*	SEM
Calcium	0.75^b	0.75^b	0.85^a	0.83^a	0.01
Phosphorus	0.39^b	0.30^b	0.41^a	0.33^b	0.02
Potassium	1.20^b	0.70^d	1.40^a	0.93^c	0.03
Magnesium	0.19^c	0.44^a	0.46^a	0.34^b	0.01
Sodium	0.05	0.06	0.05	0.06	0.01

^{abcd}: Means in the same row with different superscripts are significantly different (P<0.05).

Both the CT and phytate contents followed the same trend and were different (P<0.05) among the browses resulting in this rank order: *I. doka*>*D. microcarpum*>*S. kunthianum*>*P. thonningii* (Table 4). The fodders had low concentration of CT, which would generally be considered unlikely to significantly affect intake and digestion of nutrients in ruminants. With high CP, moderate fibre and low CT, the fodder trees would be regarded as having potentially high nutritive value, which would justify their consumption, by ruminants in the studied area. The levels of CT are lower than the range of 60 to 100 g/kg DM considered to depress feed intake and growth (Barry and Duncan, 1984). Feeding tannin-containing plants can decrease ruminal protein degradation and promote microbial protein synthesis (Cardozo *et al*., 2004; Olafadehan, 2013; Olafadehan *et al*., 2015, 2016), enhance nitrogen retention (Olafadehan, 2013; Olafadehan *et al*., 2015) and prevent excessive ruminal gas formation, which can lead to bloat (Wina *et al*., 2004) and reduce methanogenesis (Olafadehan and Okunade, 2016). The phytate contents of browse sp. are lower and higher than the levels reported by Fadiyimu *et al*. (2011) and Njidda *et al*. (2013b) respectively. Similarly, the phytate content in this study is far lower than <5% prescribed as the phytic acid threshold level in ruminants (Laurena *et al*., 1994). Phytate chelates essential minerals including calcium, magnesium, iron, zinc and molybdenum (Iqbal *et al*., 2005) and the resulting chelates resist breakdown in the digestive tract and become unavailable thus inducing deficiency of these elements (NRC, 2001; Iqbal *et al*., 2005). Though most of the phosphorus in plants is organically bound to phytic acid (Maga, 1982), ruminants are endowed with enzyme phytase which breaks down the phytate-phosphorus complex in the rumen. Both saponins and oxalate concentrations were highest ($P<0.05$) in *I. doka* compared to other fodders. The values obtained for the two phytochemicals are higher than the concentrations reported for some browse species by Njidda *et al*. (2013b). Since dietary saponins are poorly absorbed, their biological effects occur in the digestive tract (Cheeke, 1996). The defaunating properties of saponins and ability to mitigate enteric methane production (Hu *et al*., 2005) have been reported. Therefore, the browses can be used as environmentally friendly fodders for mitigating ruminant contribution to greenhouse emission. Earlier reports have implicated oxalates in the impaired metabolism of Mg in livestock (Mead *et al.*, 1985). Norton (1994) observed that the concentration of oxalic acid in leaves may decrease the availability of Ca during digestion or deplete the Ca reserve in the body. However, the relatively low content of oxalates in the browse fodders would ensure Ca stabilization and availability during digestion.

Table 4: Phytochemical components (% DM) of the experimental fodders

	P. thonningii	*D. microcarpum*	*S. kunthianum*	*I. doka*	SEM
CT	0.24^{d}	0.68^{b}	0.42^{c}	0.92^{a}	0.02
Saponins	2.55^{b}	1.46^{c}	0.99^{b}	2.86^{a}	0.11
Phytate	0.48^{d}	0.84^{b}	0.66^{c}	1.02^{a}	0.03
Oxalates	0.83^{c}	1.02^{b}	0.64^{d}	1.62^{a}	0.01

^{abcd}: Means in the same row with different superscripts are significantly different ($P<0.05$).
CT: condensed tannins

CONCLUSION
The results of the present study underscore the potentials of studied browses as nutritive fodders for ruminant animals. However, further *in vitro* and *in vivo* trials involving these browses should be conducted to establish their feeding value.

CONFLICTS OF INTEREST
The authors declare no present or potential conflicts of interest.

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